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(71) Applicant: ENGELHARD CORPORATION, 70 Wood
Avenue South CN 770, Iselin New Jersey 08830 (US)

(72) Inventor: Early, Jack, 698 Franklin Drive, Perth Amboy
New Jersey (US)
Inventor: Fekete, Imre, Deceased (US)
Inventor: Werth, John, 204 Bertrand Drive, Princeton
New Jersey (US)

(74) Representative: Colgan, Stephen James et al,
CARPMAELS & RANSFORD 43 Bloomsbury Square,
London WC1A 2RA. (GB)

(54) Fuel cell/battery hybrid system having battery charge-level control.

(57) A fuel cell/battery hybrid power system is disclosed which
has a microprocessor based control system. The control sys-
tem enables the fuel cell to be taken out of the system by a
switch when its predetermined maximum desired energy out-
put is about to be exceeded by load requirements. The battery
is protected from overdischarge through a switch. The switch
can be activated in response to the sensing of state of charge,
load current and fuel cell current. The surge battery is selected
as the battery having the highest level of charge at any given
time.

EP 0 136 187 A2

FUEL CELL/BATTERY HYBRID SYSTEM
HAVING BATTERY CHARGE-LEVEL CONTROL

5   BACKGROUND OF THE INVENTION

This invention relates to hybrid power systems and, more particularly, to the control of such systems.

10   In planning for future energy needs based on an evaluation of existing and potential economic and ecological problems, a great deal of attention is being given to the development and utilization of energy efficient systems. Of particular interest are devices

15 capable of generating electricity by consuming plentiful or renewable fuels, the utilization of which minimizes environmental pollution which is economically justified. Fuel cells and gas turbines utilizing low weight hydrocarbons or hydrogen obtained by reforming

20 methanol or similar organic fuels represent likely candidates in this area. The fuel cell typically has a high efficiency and is largely without polluting emissions. Noteworthy also is the versatility of the fuel cell in respect to size and power level which is

25 by adaptability to a modular design. Additionally , the fuel cell requires few moving parts, and is a quiet, reliable and comparatively maintenance free source of electric power.

The above factors have made the fuel cell a

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likely candidate for use in specialized vehicle transportation where needs are well defined and long-standing. Unfortunately, fuel cells do not generally operate as well as desired under conditions

5 in which substantial variation in the load or surge demand are encountered. Fuel cell components can be damaged by surge demands due to overheating, or the surge demand may not be met at all. To overcome this problem, attempts have been made to utilize fuel cell

10 stacks as primary energy sources in a so called "hybrid system", the purpose of which is to allow use of the major energy source (fuel cell) in a near optimum design by supplying only the average load requirements directly therefrom.

15 Such a system includes a storage source, such as a battery, to supply the transient load increases and which can be recharged when the load drops below average. Thus, the load variation experienced by the primary energy source or fuel cell is reduced in

20 frequency and magnitude. This allows for design and operation of the fuel cell to be within a band representing the average load rather than designing for peak load with dominant operation under peak load conditions.

25 Reduced emissions and increased efficiency are the expected benefits for operating the hybrid system. A prior art type of hybrid power device is disclosed in an article by J.B. O'Sullivan et al "Hybrid Power Source For Material Handling Equipment",

IECEC 1975 Record, pp 229 - 236. In the system
described by O'Sullivan, four fuel cell stacks are in
parallel with a battery sub-system. A controller
controls the fuel cell and battery sub-systems to limit
5   the total current from the fuel cell to maintain the
fuel cell's life and to limit the fuel cell sub-system
voltage as protection for the batteries. At low
currents, the fuel cell sub-system voltage rises
rapidly and fully charged batteries would be driven
10 into strong gasing if not protected. The O'Sullivan
controller operates to vary a series resistance between
the fuel cell stack and the batteries, resulting in a
variable voltage drop to maintain the voltage constant
at the battery at low currents and maintain the voltage
15 constant at the fuel cell at high currents.

        Although the system described in O'Sullivan
provides an approach to control of the system, the
degree of control may not be optimal since
significient resistive losses occur during operation.
20 Further, O'Sullivan does not specify how the sharing of
load current demand is provided between the fuel cell
stack and the batteries. Therefore, it appears that
the O'Sullivan system does not provide a technique in
which the peak surge energy demands in a hybrid system
25 are compared to the average load requirements, and
appropriate adjustments are made in the system, so that
either the batteries alone or the fuel cell and the
battery are utilized in some combination to meet the
load demand in a most efficient manner.

In addition to the O' Sullivan article, the following U.S. patents are of general interest in the fuel cell area: 4,000,003; 3,883,368; 3,753,780; 3,546,020; and 3,473,337, and are mentioned herein as a matter of general background.

5   Other fuel cell/battery hybrid systems of interest are disclosed in "Fuel Cell Systems for Vehicular Applications", SAE Technical Paper Series, 800059, by Lynn, McCormick, Bobbett and Derouin, February 25-29, 1980; "A Fuel Cell-Battery Power 10 Source for Electric Vehicles", The Fifth International Electric Vehicle Symposium, 782407(E), by Dowgiallo, Oct. 2-5, 1978; UK Patent Application GB 2 084 387 A, published on April 7, 1982; "An Assessment of the Status of Fuel Cell/Battery Vehicle Power Systems", by 15 Escher and Foster, February, 1980; Report CONF-800523-1 of the International Electric Vehicle Exposition and Conference by Bobbett, McCormick, Lynn, Kerwin and Derouin, May, 1980.

20   **SUMMARY OF THE INVENTION**

The present invention provides an improved hybrid power system wherein an energy storage means, such as batteries, and a primary energy source, such as 25 a fuel cell stack, are selectively and automatically connected in parallel circuitry through switching means to a common load, under control of a microprocessor. The system is designed so that the power output of the

primary electrical energy source does not exceed a maximum design power output and the energy storage means may be controlled so that it has a predetermined desired maximum and minimum level of charge

5   maintainable at all times. A controller regulates these aspects for optimum use of the hybrid system.

In an embodiment of the invention, a load sensor is provided to monitor the load current and sensors can be provided to measure the state of the

10   charge at each of the batteries. If the load sensor indicates a very load high current, the microprocessor activates the appropriate switching means such that both batteries are connected to the load with the fuel cell stack disconnected. If the load sensor indicates

15   a high current demand, the microprocessor causes both batteries and the fuel cell stack to be connected into the load. If the load sensor indicates a medium current demand, the fuel cell stack and the battery which has a higher state of charge is connected by the

20   microprocessor to the load. Finally, if the load sensor indicates a low current load demand, the fuel cell and any of the batteries that are charged to a value less than a predetermined value are connected into the system. In essence, the system described herein

25   manages energy transfers between the storage device and the primary energy source in an electric hybrid system, such as a fuel cell-battery system.

In an embodiment of the invention, the batteries and the fuel cell stack are either connected

to or disconnected from the common load in a sequence
determined by a microprocessor based on instantaneous
load demand and battery state of charge conditions. As
a result, system surge capability is enhanced while
5   peak power output of the primary energy source is
controlled. Although the system is operable with a
single battery, it is preferred in some embodiments
that at least two or more batteries be utilized since a
multiple-battery system enhances system reliability by
10 avoiding the problem of a single bad cell in one of the
batteries causing the entire system to become
inoperable. The concept also provides operational
flexibility in that, while one battery is being cycled,
the other battery equalizes and cools off. The system
15 also enhances flexibility in system configuration and
package design. This embodiment also provides means
for enhancing the overall efficiency of the hybrid
system since various energy source combinations are
possible depending on the battery charge level and the
20 current load. Switching between the power sources is
arranged to provide for maximum efficiency by allowing
the fuel cell stack to operate close to its average
rated power output for all load demand conditions. The
fuel cell, when connected to the load, is also utilized
25 to charge the batteries as appropriate, the shifting of
load to the fuel cell stack minimizing battery-run down
by avoiding battery overcharge or overdischarge. This
aspect extends battery life.

In an embodiment of the invention, a first

and second battery are used with a fuel cell, the batteries each having a desired minimum level of charge during operation. If on system start up, both batteries are fully charged, the first is used as a
5 surge battery until it nears or reaches its desired minimum level of charge. At that time, the second battery replaces the first as the surge battery and the first is recharged by the fuel cell during periods of low load conditions. In such a two battery hyrbid
10 system, the surge battery can be selected by the controller as the one having the highest level of charge at any given time.

In another embodiment of the invention, a single energy storage means, such as a battery, is
15 utilized with a fuel cell and protection is given against the battery being overcharged. The battery has a predetermined maximum and minimum charge level and the load current, state of charge and fuel cell current are utilized to maintain the battery within its maximum
20 and minimum charge level limits.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing aspects and other features of
25 the invention are explained in the following description, taken in connection with the accompanying drawings wherein:
Figure 1 is a schematic diagram of the hybrid system of the present invention;

Figure 2 is a block diagram illustrating the use of a microprocessor to control which power source or sources is to be utilized to supply the common load in the circuit of Figure 1; and

5   Figure 3 is a flow chart depicting a typical program for operation of a microprocessor in the system of Figure 2.

Figure 4 is a schematic illustration of a single battery/fuel cell hybrid control system.

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DETAILED DESCRIPTION

Referring now to Figure 1, a schematic
15 diagram of the hybrid system of the present invention is illustrated. The primary energy source 10 comprises a fuel cell stack utilized in conjunction with two batteries, 12 and 14. Batteries 12 and 14 are generally rated in terms of open-circuit voltage, ampere-hour
20 capacity, and internal impedance. Both batteries operate as high power density storage devices and both are connected in parallel to fuel cell stack 10 in a manner to be described hereinafter. Although two batteries, 12 and 14, are preferably utilized in the
25 system described, either a single battery or more than two batteries could also be utilized.

A load device 16, representing, for example, the current demand from a motorized vehicle, is connected in parallel across the energy sources 10, 12

and 14 as illustrated. A plurality of relay contacts 18', 20' and 22' are connected in series with energy sources 10, 12 and 14, respectively, as illustrated. As will be described in more detail hereinafter, if the
5 contacts 18', 20' and 22' are caused to be in their closed position, the associated energy source is, in turn, connected to the load 16. Current sensing devices 24 and 26, typically ammeters, are included in series with fuel cell 10 and load 16, respectively, as
10 shown.

Charge sensors 28, and 30 are coupled in series with energy sources 12 and 14, respectively, and function to sense the energy source charge level. Typically, such devices comprise an integrating
15 coulombmeter which integrates the amperes in and out of the battery to track the total coulombs received and delivered by the battery. The charge sensor may incorporate a reset circuit to reset the coulombmeter periodically to compensate for drift in the
20 coulombmeter. The coulombmeter can be a separate unit within the system or its function could be incorporated in the microprocessor described hereinafter.

Figure 2 is a block diagram of the microprocessor-based control system used to determine
25 which combinations of energy sources are to be connected to the load 16. In particular, a programmable microprocessor 40, such as the Zilog Z80 microprocessor chip, the operation of which is described in Zilog Publication "Z80-CPU/Z80A-CPU

Technical Manual", dated September, 1978 is responsive to the output from load sensor 26 and charge sensors 28 and 30. Output signals from microprocessor 40 are coupled to relays 18, 20 and 22 via leads 41, 42 and 5 43, respectively, relays 18, 20 and 22 controlling respective contacts 18', 20' and 22' shown in Figure 1.

In essence, the output of load sensor 26 determines the operational mode of hybrid power system 8. As will be set forth in more detail hereinafter, 10 four modes of operation selected corresponding to a very high, high, medium, and low load currents.

The qualitative definition of a low mode is one in which the entire load can be delivered by the fuel cell alone without help from any battery. The 15 medium mode is where the fuel cell requires the assistance of at least one battery to meet the load demand without the fuel cell being overloaded. The high mode is where the fuel cell and two batteries would be required to meet the demand, one battery not 20 being sufficient. The very high mode is where the fuel cell would have to be disconnected because, even with both batteries assisting, the fuel cell would be overloaded and subject to damage.

In a representative 5 kilowatt system, for 25 example, a low mode would correspond to a load rating not higher than approximately 6 kilowatts (e.g., 50 volts, 120 amperes); the medium mode would correspond to a load rating not higher than approximately 10 kilowatts (e.g., 200 amperes); the high mode would

correspond to a load rating not higher than approximately 15 kilowatts (e.g., 300 amperes); and the very high mode would correspond to a load rating not higher than approximately 25 kilowatts (e.g., 500
5 amperes).

It should be noted at this point that adapting a microprocessor, such as the aforementioned Zilog Z80, to control various process operations such as the switching sequences described herein, can be
10 accomplished by one of ordinary skill in the art having familiarity with the particular process requirements. It should also be noted that a circuit having standard analog or digital components could be utilized in lieu of microprocessor 40 to provide the required switching
15 sequence.

Referring back to Figure 2, if the load sensor 26 determines that the load current is very high, microprocessor 40 generates signals on leads 41, 42 and 43 such that contact 18' is opened and contacts
20 20' and 22' are closed, to connect batteries 12 and 14 in parallel to the load 16 while the fuel cell is disconnected from load 16. If the load sensor 26 detects a high load current, a signal is applied to relays 18, 20 and 22 so that each of the appropriate
25 contacts 18', 20' and 22' are closed, each of the energy sources 10, 12 and 14 therefor being connected in parallel to provide the current demand of load 16.

If the load sensor 26 detects a medium condition, microprocessor 40 generates a signal on lead

41 such that relay 18 is activated, contact 18' being closed thus connecting fuel cell stack 10 to load 16. In this case, the microprocessor 40 first senses the battery charge levels as determined by sensors 28 and

5 30. The microprocessor determines whether battery 12 and 14 has the higher state of charge and that battery is connected by the microprocessor to the load 16 by energizing the appropriate relay. In other words, if sensor 28 indicates that battery 12 has a higher state

10 of charge than the charge of battery 14 as determined by sensor 30, relay 20 is activated such that corresponding contact 20' (Figure 1) is closed connecting battery 12 to load 16, while contact 22' remains open. If the charge level determination is

15 reversed, relay contact 22' is closed and relay contact 20 is opened, connecting battery 14 to load 16. In both these cases, relay contact 18' is closed, connecting fuel cell 10 to load 16.

Finally, if the load sensor 26 determines

20 that a low load current is demanded, relay 18 is activated, closing relay contact 18' and thus connecting fuel cell 10 to load 16. Microprocessor 40 then determines which of the batteries 12 and 14 is charged to less than a predetermined typically the 90%

25 level. All those batteries which are less than that predetermined level are then connected into the circuit by closing the appropriate contacts via relay 20 or 22 as required. Specific variations of the above microprocessor control scheme are set forth hereinbelow

with reference to Tables I-IV.

The present invention is further explained with reference to Table I in which the switching mode of the primary electrical energy source, such as the

5 fuel cell in this embodiment, and the first and second batteries are shown with respect to four general load demand or mode conditions. A minimum acceptable battery charge of 70% and a maximum of 90% is assumed, although variation in range is permissible, depending

10 on the environment in which the system is used.

In Table I, at "Low" sensed current demand, for example, if both batteries are assumed to be at an arbitrary preset maximum 90% charge level, then no charge is imposed even though load demand on the

15 primary energy source is less than the rated constant output of the primary energy source. It is noted that four possible battery configurations may be provided.

Under "Medium" sensed load (Table I), the primary energy source plus either battery 12 or 14 are

20 available to meet a demand somewhat exceeding that provided by the primary electrical energy source. This choice may be mandated as battery 12 in one instance and battery 14 in the other, depending on which is more highly charged. Such is then also the case in Tables

25 II, III and IV, at a comparable demand level, since the battery of higher sensed potential, within the selected maximum and minimum range of 90%-70% charged level, is automatically selected as the surge battery to supplement the primary electrical energy source, while

the second battery remains in open (non-flow) bias.

Under "High" sensed energy demand (Table I), both batteries 12 and 14 and the primary energy source are utilized to fully meet power demands on the system
5 substantially in excess of the output of the primary energy source. The response is consistent at this surge demand (see also Tables II, III) so long as the charge on each battery is greater than a preset 70% minimum charge level or other convenient minimum
10 depending upon use of the system. When both batteries are charged as shown in Table IV, neither battery would be connected when the load is low. The microprocessor is tied into all the switches to accomplish their change of states when desired to function as intended.
15 In all of the Tables used herein, the following legends are used:

    O - Open Contact - no current flow
    + - Closed Contact - Current flow in parallel
    C - Charging Mode

20

TABLE I

SENSED LOAD	FUEL CELL 10	BATTERY 12	BATTERY 14
Very High	0	+	+
High	+	+	+
Medium	+	+	0
	+	0	+
Low	+	0	0
	+	0	C
	+	C	0
	+	C	C

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Table II further exemplifies operation of the system of Figure I when one of the batteries 12 is at 90% charge and the other battery 14 at 85%.

TABLE II

SENSED LOAD	FUEL CELL 10	BATTERY 12 (90% chg.)	BATTERY 14 (85% chg.)
Very High	0	+	+
High	+	+	+
Medium	+	+	0
Low	+	0	C

Table III further exemplifies operation of the system of Figure I when both batteries have a relatively low charge level but equal or exceed a preset 70% minimum charge level.

TABLE III

SENSED LOAD	FUEL CELL 10	BATTERY 12 (70% chg.)	BATTERY 14 (75% chg.)
Very High	0	+	+
High	+	+	+
Medium	+	0	+
Low	+	C	0
	+	C	C

Table IV further exemplifies operation of the instant system when battery 14 is at a 90% charged level and battery 12 is also at a 90% charged level.

TABLE IV

SENSED LOAD	FUEL CELL 10	BATTERY 12 (90% chg.)	BATTERY 14 (90% chg.)
Very High	0	+	+

High	+	0	+
Medium	+	0	+
Low	+	O	O

The batteries 12 and 14 are recharged by the fuel cell stack 10. In particular, whenever the charge sensors 28 and 30 indicate that the state of charge is greater than 90% during the operating part of the power cycle, the batteries are prevented from continuing to charge and thus, are disconnected from fuel cell stack 10 under control of microprocessor 40. Otherwise the batteries would be damaged. At the same time, if the state of charge falls below some minimum state of charge; i.e., 70%, the battery would not be allowed to discharge any further unless needed to meet the load. It would be a very unusual condition for either battery to be required to supply power and be 70% charged at the same time if the system is designed appropriately.

It should be noted that the battery does not

have to be disconnected from the load in order to be recharged if the load is low. For example, if the state of charge of a battery is 80%, the battery is within the safety limits and the battery can either

5 charge or discharge. Therefore, the battery can be connected to both the load and to the fuel cell stack and if the load is light, the battery will accept charge. If the load is heavy, the battery is discharging. When the limits are reached, the battery

10 is connected at low current only if it needs to be charged or at medium current only if it needs to be discharged.

In another similar embodiment of the system a single energy storage means, such as a battery, can be

15 used in combination with switches and a fuel cell to maintain an optimum hybrid system. In such an embodiment, the state of charge in the battery is continuously sensed and fed to the controller to determine if and when the battery is in danger of being

20 overcharged. The load current is also continuously monitored by the controller to determine which of three ranges of load conditions the system is operating under at any given instant. First, there is the low range within which the current is capable of being met by the

25 fuel cell alone. Second, there is the medium range within which the load current is capable of being met by the output of the fuel cell together with the battery. Third, there is the very high range within which the load current is so high that even if the fuel

cell and battery were together supplying current to the load, the current output of the fuel cell would have to be more than its predetermined load rating. The predetermined load rating of the fuel cell is designed

5   into the system beforehand and is usually based on average load expected rather than all possible load surge levels.

A schematic illustration of this embodiment of the simple, single battery/fuel cell system is shown

10   in Figure 4. Fuel cell 103 produces current as required by the load 105 and/or battery 101 for recharging the battery. Fuel cell 103 has a switch 104 which connects and disconnects it from load 105 and battery 101. Battery 101 also has a switch, switch

15   102, which connects and disconnects it from load 105 and fuel cell 103. The system also contains a suitable control means such as controller 106 which measures the current produced by the fuel cell 103 via current sensor 107 and the current drawn by load 105 via

20   current sensor 108. From these two current values, the current flowing to and from the battery 101 can be calculated as well as the state of charge within the battery. The state of charge in battery 101, can be calculated by well known integration techniques, based

25   on its current flow, by the controller 106.

Within the range of operating conditions of the system described in Figure 4, switches 104 and 102 can produce a combination of switch conditions to optimize the operation of the system. For instance,

under condition of low load and of battery 101 being in danger of overcharging, switch 102 is disconnected or opened while switch 104 is connected or closed. The reason for this is to prevent the battery from being

5   overcharged. If, conversely, switch 102 were allowed to be connected under these conditions, that portion of the current flowing from the fuel cell which was not drawn by the load would flow into battery 101 thereby tending to overcharge it.

10   Under high load conditions in the system of Figure 4, switches 102 and 104 are both connected or closed. The reason for this is that the current drawn by the load is too high to be satisfied by the predesigned capability of the fuel cell alone. Under

15   very high load conditions of the system on Figure 4, switch 104 is disconnected or opened and battery switch 102 is connected or closed. The reason for this is that if both switches were connected, the current requirements of the load would force the fuel cell

20   beyond its predetermined output capability.

          The following technique may be used in bringing the fuel cell back on line after very high load conditions occur. Such action can be carried out by measuring the voltage of the load at the point that

25   the fuel cell is disconnected therefrom under very high load conditions and storing it in the controller. After the very high load conditions pass and lower load conditions are reinstated, such as high or low load conditions referred to above in Figure 4, switch 104

should be connected to enable fuel cell 103 to produce current for load requirements. The precise time for bringing the fuel cell 103 back into the system can be determined by sensing the load voltage continuously

5 after very high load conditions begin, and closing switch 104 when the same sensed voltage reappears as the very high load conditions dissipate. Alternatively, the load current existing just before or at the disconnect of switch 104 as very high load

10 conditions appear can be sensed and placed into the memory of controller 106 so that as load conditions are lowered below the very high load conditons, as indicated by the load current being compared to the level placed in the memory of the controller, switch

15 104 can again be connected to bring the fuel cell 103 onto the system.

The following Tables V through VII depict the various conditions of the system elements similarly to the previous Tables. However, there are only three

20 operating load conditions instead of four; low, high and very high, for this embodiment.

Table V shows a general case of the various possibilities in connecting the fuel cell and battery under the three load range conditions of the embodiment

25 in Figure 4.

TABLE V

SENSED LOAD 105	FUEL CELL 103	BATTERY 101
Very High	O	+
High	+	+
Low	+	O
	+	C

Table VI shows the three operating load conditions when battery 101 is 90% charged, or fully charged for this case.

TABLE VI

SENSED LOAD 105	FUEL CELL 103	BATTERY 101 (90% chg.)
Very High	0	+
High	+	+
Low	+	0

Table VII shows the three operating load conditions when battery 101 is 80% charged and can be recharged during low load conditions.

TABLE VII

SENSED LOAD 105	FUEL CELL 103	BATTERY 101 (80% CHG.)
Very High	O	+
High	+	+
Low	+	C

Thus, it can be seen that the control system disclosed herein can utilize one, two or more batteries with the fuel cell. Each battery utilized can have a switch associated therewith which can connect and disconnect it to the system as dictated by the microprocessor. The system may also have means to sense the fuel cell current, the load current and the state of charge in the batteries. The batteries may have a desired predetermined maximum and minimum state of charge during operation and one of the batteries, in a multiple battery system, may be used as the surge

battery until it reaches its predetermined minimum charge level. At such time another battery in the system of high charge level can replace it and the battery recharged by the fuel cell under low load conditions. Also, in a two battery system, the surge battery can be selected by whichever battery is at the highest charge level.

The present invention thus provides many advantages over the prior art hybrid power systems. In particular, a commercially available microprocessor may be utilized to function with a proper combination of energy sources coupled into the load in a manner such that the load capacity of the fuel cell is not exceeded while the system surge capability is enhanced. The above system protects the batteries against overcharge and overdischarge and also protects the fuel cell from overloading by sensing the battery charge levels and the load current, respectively, and switching the batteries and the fuel cell to obtain the best possible and most efficient system utilization.

It is to be understood that the above described embodiment of the invention is illustrative only and that modifications thereof may occur to those skilled in the art. Accordingly, this invention is not to be regarded as limited to the embodiment disclosed herein, but is to be limited only as defined by the appended claims.

CLAIMS

1.   A hybrid power source system for controlling the amount of current supplied from an energy source in response to current demand from a load characterized in that the system comprises:

a primary electrical energy source having a predetermined maximum desired power output, said source having first switch means associated therewith;

energy storage means having a second switch means associated therewith; either said primary electrical energy source or said energy storage means or combinations thereof being connected in parallel to supply current to said load depending upon whether said first or second switch means or a combination thereof is appropriately energized;

means for sensing the current flowing into said load;

means for sensing the state of charge in said energy storage means;

means responsive to said load current sensing means for selectively energizing either said first and/or second switching means in a manner such that the current demand on said primary electrical energy source is maintained at or below approximately its predetermined maximum desired power output level; and

means to recharge said energy storage means as needed at a time said primary electrical energy source is operating below its predetermined maximum desired power output.

2. The system of claim 1 characterized in that said energy storage means has a predetermined desired minimum and maximum level of charge and further characterized in that the system has a means for sensing the current flowing from said energy source so

that said responsive means is responsible to said load current sensing means, said means for sensing the current flowing from said primary energy source and said means for sensing the state of charge in said energy storage means for selectively energizing either said first or second switching means in a manner such that the current demand on said primary electrical energy source is maintained at or below approximately its predetermined maximum desired power output level and said energy storage means is maintained at a charge level between said minimum and maximum charge level.

3. The system of Claim 2 characterized in that said first switch is closed and said second switch is opened during such time that there is a low load condition and energy storage means is at or just below its predetermined desired maximum level of charge.

4. The system of Claim 2/characterized in
  or Claim 3
that said first and second switches are closed during such time that there is a high load condition.

5. The system of any of / characterized in
  Claims 2, 3 and 4
that said first switch is open and said second switch is closed during such time as that there is a very high load condition.

6. The system of Claim 1 characterized in that said energy source comprises a first energy

storage means having said second switch means associated therewith and a second energy storage means having third switch means associated therewith, either said primary electrical energy source, said first and second energy storage means or combinations thereof being connected in parallel to supply current to said load depending upon whether said first, said second and third switch means or combination thereof are appropriately energized, said first and second energy source means having respective predetermined desired minimum and maximum level of charge, and said responsive means being responsive to said load current, sensing means for selectively energizing either said first, second or third switching means in a manner such that the current demand on said primary electrical energy source is maintained at or below approximately its predetermined maximum desired power output level.

7.   The system of Claim 6 characterized in that the selection of the energy storage means changes as the state of charge of the energy storage means previously selected drops below the state of charge of the other energy storage means.
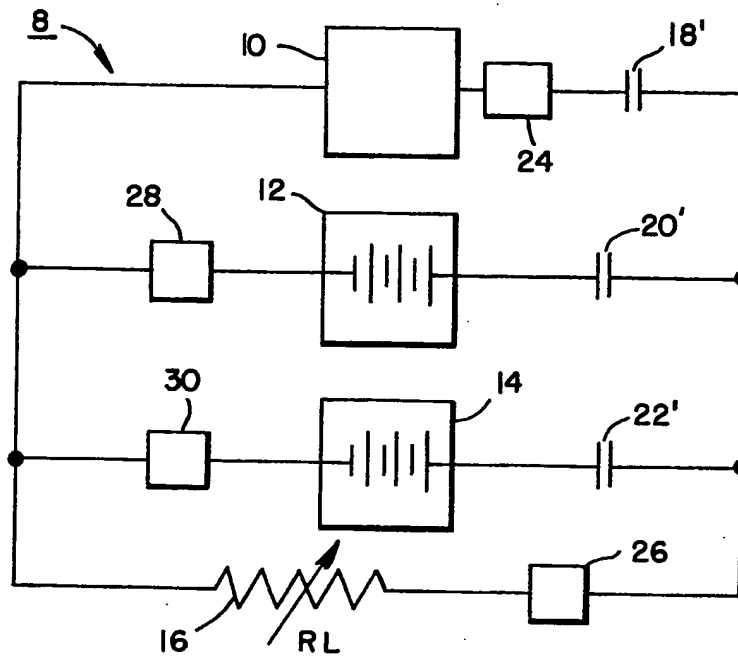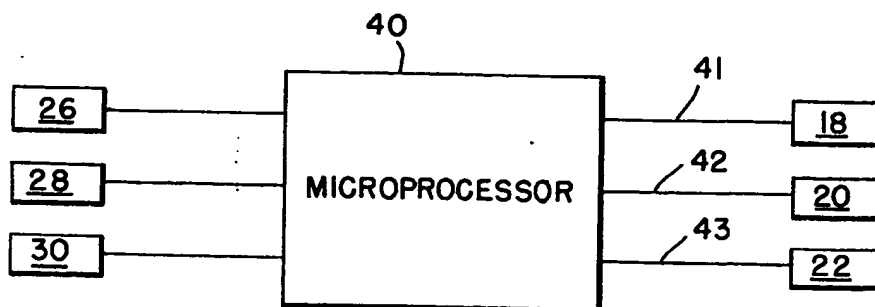
8.   The system of Claim 7 characterized in that said primary electrical energy source recharges the energy storage means unselected as the energy storage means as needed during periods when the load is not drawing the full output of said primary electrical
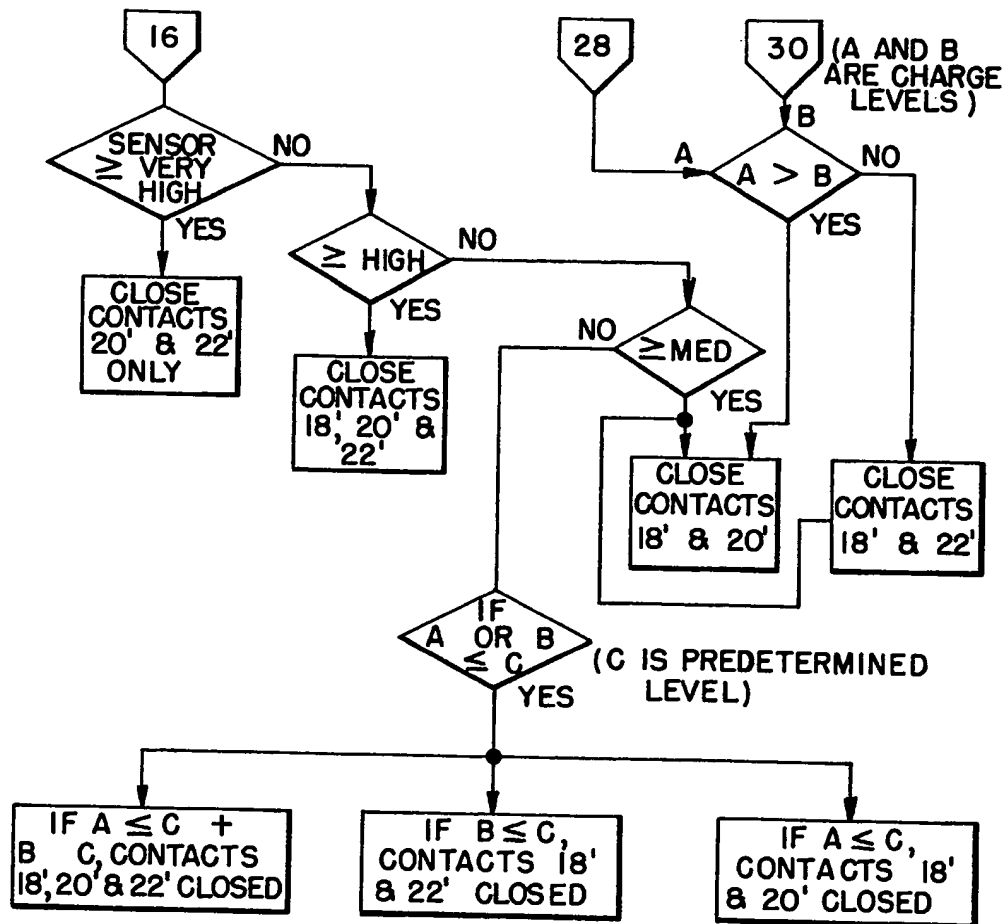
energy source.

9.   The system of/Claim ^{any preceding} characterized in that said energy storage means comprises storage battery means and said primary energy storage comprises a fuel cell means.

10.   The system /of Claim ^{any preceding} characterized in that the number of energy storage means is greater than two and each has a switch associated therewith for connecting and disconnecting it from the system.

FIG. 1.

FIG. 2.

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2/2

FIG. 3.

FIG. 4.